Roseate terns on Aride Island: the contribution of 19 years of monitoring to the conser ation of an endangered species

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Abstract: The roseate tern *Sterna dougallii* on Aride Island has been studied extensively and intensively since 1984. This paper assembles 19 years of data on roseate tern breeding numbers and productivity in order to identify possible limiting factors and assist the conservation of the Aride population. Between 1984 and 1995 the breeding population was estimated from counts of incubating birds from suitable viewpoints. Since 1996 all nests have been counted 18 days after the laying of the first egg. Until 1996 chick survival and productivity (n° of chicks fledged per breeding pair) were estimated from regular visits to viewpoints. Since 1997 reproductive parameters have been studied in detail in study quadrats. Studies of nest-site selection, foraging habitats, diet, chick-feeding rates and impact of ticks on breeding success and chick survival were conducted between 1997 and 1999. Overall, the breeding population crashed from 4,300 - 4,800 in the 1970s to about 1000 pairs in 1988. Since 1988 the breeding population has shown wide annual fluctuations. In spatial terms there was a tendency for concentration into only one major colony. In the 1980s, about 50% of the roseate terns nested in an open area, the Lodge Glade, but this colony was abandoned in early 1990s, apparently due to growth of *Asystasia* sp. a herb that densely carpeted the area, entangling both adults and chicks. The spatial distribution of colonies suggests that roseate terns may avoid areas with Sooty Terns. Within colony-sites roseate terns select concealed nest-sites. These appear to protect chicks from attacks of adults and kleptoparasitism. Goatfish (Mullidae) comprised the large majority of the food delivered to chicks. The breeding success was determined by food shortage, tick infestation and intraspecific aggression of chicks by adults. Food shortage appears to be the most important factor; ticks and adult intraspecific aggression are additive to food shortage. In 19 years of monitoring on Aride, roseate terns failed almost completely during half of them. It is suggested that annual variations in marine productivity may be the ultimate factor determining roseate tern timing of breeding and, therefore, productivity. Lack of predatory fish to drive prey to the surface may contribute to explain intermediate periods of food shortage. The postbreeding ecology of the Aride-Roseate Terns is unknown. The most critical parameters in need of research for this population are adult survival and recruitment rates. This is important in order to assess which are the main limiting factors: productivity or adult survival. Research into these areas remains the only key to formulate possible management decisions. Hopefully, the ringing scheme started in 1997 will elucidate this point.

Key-words: Roseate tern, conservation, monitoring, Aride, Seychelles

Introduction

The roseate tern (*Sterna dougallii* Montagu, 1813) is an endangered seabird species with a world-wide distribution. The stronghold of this species is in the Indian Ocean (Gochfeld 1983), but there are important populations in the United States, Europe (Ireland and the Azores Islands, Portugal), Australia (Great Barrier Reef), the Caribbean and Japan. The roseate tern has declined since the 1970s but numbers have stabilised recently. The declines in the North-American (Nisbet & Spendelow 1999) and European (Avery & del Nevo 1991) populations have been well documented, but the most abundant tropical populations have received little attention. In Europe it is classified as Endangered because of its large decline in numbers (Tucker & Heath 1994). The total world population is estimated at 20.000–30.000 pairs, of which 15,000–22,000 may be in the western Indian Ocean (Gochfeld 1983). Very

little is known of this species in the Indian Ocean, apart from the population on Aride Island, Central Seychelles. Small roseate tern colonies were formerly scattered around Central Seychelles and in the Amirantes. Nowadays the only known colonies are on Aride and in the Amirantes (African Banks and Etoile, Feare, pers. comm., Skerett 1996). The roseate tern on Aride (for some regarded as the subspecies *Sterna dougallii aridensis* (Warman 1979) has been studied extensively and intensively since 1984. Reports with that information are kept on Aride Island, and the general office of the RSNC. The main aims of the research were to provide information on breeding numbers and productivity in order to identify possible limiting factors and assist the conservation of the Aride population. Since 1997 detailed information on reproductive parameters has been collected, along with the several ecological factors that were likely to explain annual variation in breeding numbers and reproductive rates.

This paper summarises 19 years of roseate tern monitoring and research on Aride Island and its contribution to the conservation of this endangered species.

Methods

Breeding population estimates

The breeding population was estimated in 1975 and every year since 1984. Between 1984 and 1995 the breeding population was estimated without intrusion into the nesting areas. Counts of incubating birds were made before chicks started to hatch, from suitable viewpoints, walking around the edges of the colonies and/or from temporary hides (Ayrton 1993, 1994; Maul 1998, Bowler et al. 2002). Since 1996 all nests have been counted 18 days after the laying of the first egg, a method found feasible and applied in colonies in Europe and North America, in terms of reliability of population estimates and minimization of disturbance (Ratcliffe & del Nevo 1995). Since 1997, two quadrats have been established (except in 2000) in the main colony, with corner posts and string, 16 days after the first egg was seen: one peripheral and less dense quadrat (49 m^2) and one more central and denser quadrat (64 m^2). The sample size for each quadrat was increased with adjacent nests. All nests in these plots were marked with numbered pegs and counted before and after the main count, in order to estimate the proportion of nests missed by the count. In addition, all nests in front of a permanent hide were mapped between 1997 and 1999, at the time of egg laying. The position of each clutch and the fate of eggs and chicks were monitored daily (Ramos 2001). This allowed to estimate the proportion of clutches lost prior to nest marking.

Reproductive parameters

Until 1996 chick survival and productivity (n° of chicks fledged per breeding pair) were estimated from regular visits to viewpoints to count the number of chicks in sampling areas. At the end of the breeding season sampling areas and the rest of the colony were surveyed for dead chicks (Ayrton 1993, 1994; Maul 1998).

Since 1997 reproductive parameters have been studied in detail. During up to 30 minutes daily visits to the study quadrats and sub-colonies, eggs were measured (length and breadth), chicks were ringed and weighed at hatching and, thereafter, whenever they were encountered (Ramos 2001). Likely causes of chick mortality, notably intraspecific aggression by adults and infestation by ticks (*Amblyomma loculosum*) were recorded for chicks in the study quadrats and noted in a sampling area from a permanent hide (Ramos *et al.* 2001).

Fledglings have been ringed with metal rings (right leg) and special rings with four-character inscriptions (left leg) also used in Europe (Casey *et al.* 1995) and North America (Nisbet and Spendelow 1999). The special rings are made from incoloy and can be read with a telescope at ranges of 15-25 m.

Ecological studies

Studies of nest-site selection, foraging habitats, diet, chick-feeding rates and impact of ticks on breeding success and chick survival were conducted between 1997 and 1999 (Ramos 1998a, 2000, 2001, 2002, Ramos *et al.* 2001).

Results

Colony size and distribution

Three main colony sites have been used regularly on Aride since 1984: The Lodge Glade, Bois Tortue and Western Woodlands (Fig. 1). The breeding population of the first two colonies has decreased gradually (the Lodge Glade is not used since 1993) and virtually all breeding birds are now concentrated in the Western Woodlands colony (Table 1). This colony comprises a main colony and small sub-colonies. In 1988 some of these groups were quite distant from the main colony (Fig. 1). Since 1997 there are only two groups, about 20-30 m distant from the main colony. Between 1997-2001 the number of breeding pairs of these two groups decreased markedly: (1) 12, 9, 3, 2, 2; (2) 6, 2, 0, 0, 1, which shows further the tendency for concentration of the breeding population into only one major colony.

In 1998 a new colony of 106 breeding pairs was established in the western woodlands rocks. This colony held 88 breeding pairs in 1999 but it was not used in 2000 and 2001. Otherwise irregular small colonies of up to 6 breeding pairs have been located on the western (Ramos 1997) and eastern (Hunter & Bradbury 2001) rocks. Overall, the breeding population crashed from 4,300 – 4,800 in the 1970s (Warman & Todd 1984) to about 1000 pairs in 1988. The estimate of 9000 breeding pairs in 1984 was considered unreliable by Bullock (1989).

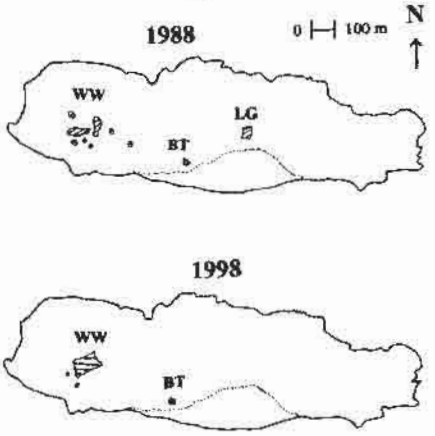

Fig. 1. Distribution of regular colonies on Aride (Bullock 1989; Ramos 1999). LG= Lodge Glade, BT= Bois Tortue, WW= Western Woodlands. There have been irregular colonies on western (1998-9, Ramos 2002) and eastern sides (2000, Hunter & Bradbury 2001).

Table 1. Population estimates, date of first egg and breeding success for Roseate Tern on Aride between 1984-2001.

Year	No. breeding pairs per colony			Total population (breeding pairs)	Date of 1st egg	Breeding success (chicks fledged)	Ref.
	Lodge Glade	Bois Tortue	Western Woodlands				
1975				4,300 – 4,800			1
1984				9000[1]	19 May (?)	flying young	2
1985				No data	1 June	0	3
1986				2000-3000	19 May	0	3
1987	800	50	800	1500-1750	5 June	0	4
1988	550	30	500	1080	12 May	75-150	4
1989	400	15	700	1115	29 May	558-583	5
1990	500	25	750	1275	28-29 May	316	5
1991	-	-	-	No breeding	No breeding	0	6
1992	170	20	420	610	4 June	25-30	6
1993	50	25	240	315	4 June	141	7
1994	0	22	404	426	19 May	203	8
1995	0	11	600	611	29 May	300	9
1996	0	13	1242	1255	13 May	400-500	10
1997	0	7	863 (1106)[2]	876 (1119)[2]	1 June	< 10	11
1998	0	8	954 (1151)[2]	1068 (1265)[2]	17 May	678-708	12
1999	0	4	1108 (1257)[2]	1200 (1349)[2]	14 June	0	13
2000	0	3	604 (1292)[2]	612 (680)[2] (1200)[3]	3 June	15	14
2001	0	4	729 (817)[2]	733 (824)[2]	16 May	170	15

References: 1 - Todd 1975 (in Bullock 1989), 2 - Tyzack & Volcere 1984, 3 - McCarthy 1986, 4 - Bullock 1989, 5 - Castle & Mileto 1991, 6 - Lindstone-Scott 1993, 7 - Ayrton 1993, 8 - Ayrton 1994, 9 - Maul 1996, 10 - Maul 1997, 11 - Ramos 1997, 12 - Ramos 1998b, 13 - Ramos 1999, 14 - Hunter & Bradbury 2000, 15 - Ramos & Pacheco 2001

[1] Estimate considered unreliable by Bullock (1989).

[2] Count adjusted for the number of nests missed in the main colony.

[3] A new influx of birds appeared in early July. It was estimated that by then the number of birds in front of the permanent hide (the study area) doubled the number of birds present in June, so the estimate of about 1300 breeding pairs (Hunter & Bradbury 2001).

Table 2. Correction of the Western woodlands main colony nest count since 1997

Year	N° of nests counted	N° of nests marked	% of nests missed	Mean % of eggs missed
1997				28.8
Quadrat 1	23	31	25.8	
Quadrat 2	54	79	31.7	
1998				20.9
Quadrat 1	15	17	11.8	
Quadrat 2	49	70	30.0	
1999				14.9
Quadrat 1	22	23	4.2	
Quadrat 2	52	70	25.7	
2001				12.5
Quadrat 1	6	8	25	
Quadrat 2	13	13	0	

In 1997 the breeding population of the main woodland colony was estimated with two methods: (1) walking around the edge of the colony and (2) a total nest count 18 days after the first egg was laid. Both methods produced similar figures: 800-900 vs 845. This gives support to the fact that population estimates between 1986 and 1995 were fairly accurate.

Between 14.9% and 28.8% of the nests were missed during the main count between 1997 and 2001 (Table 2). Roseate terns laid mostly in concealed sites and their eggs were well camouflaged amongst the leaf litter, which should account for the nests that were missed. Since 1997 two figures have been produced: a total nest count and an adjusted count for the number of eggs missed (Table 1). The first figure should be more comparable with previous estimates.

Colony and nest-site selection

Aride is the only location in the world where roseate terns are known to nest under a tree canopy (the sooty tern *Sterna fuscata*, the most abundant ground-nesting seabird on Aride also nests under the tree canopy, unlike in other areas throughout its range (Feare et al. 1997). In the 1980s, about 50% of the roseate terns nested in an open area, the Lodge Glade, but this colony was abandoned in early 1990s (Table 1). This abandonment was partially blammed on the growth of *Asystasia* sp, a herb that densely carpeted the area, entangling both adults and chicks (Ayrton 1993). Despite clearance of *Asystasia* the birds abandoned this colony in 1993, following two years of null breeding success (Ayrton 1993, 1994). Since 1994 no adults have been observed investigating this colony and the area is now occupied by sooty terns.

The two main woodland colonies, Bois Tortue and Western woodlands are fairly isolated from sooty tern breeding areas. The colonies established by roseate terns on the western roosting rocks in 1998 and 1999 were on the edge of areas occupied by sooty terns. Altogether these observations suggest that roseate terns may avoid areas with sooty terns.

Within colony-sites roseate terns select concealed nest-sites: closer to rocks or logs than random points (Ramos 1998a). Concealed sites, especially those with overhanging rocks, appear to protect chicks from attacks of adults and kleptoparasitism (Ramos 1998a).

Predation

Aride Island is secure from predation by mammals and mainland-based birds. Rats were never recorded on Aride. Goats, cats, dogs and pigs were present on Aride during the XX century (Warman & Todd 1984) but their effect on the Roseate Terns was not documented. In the 1980s and 1990s the only predators recorded were Barn Owls *Tyto alba* introduced from South Africa to the Seychelles); which were recorded to kill up to 18 adults in 1996 (Maul 1998). Active management reduced Barn Owls to a few adults (Betts 1998, Bowler and Hunter 2001) and virtually no Roseate Tern adults have been predated since 1997.

The sticky *Pisonia grandis* seeds have also been responsible for the death of some adults in certain years, when breeding coincides with heavy fruiting, such as in 1994 (Ayrton 1994).

Diet and foraging habitats

Roseate Tertn are specialised predators on small schooling fish. Goatfish (Mullidae: *Parupeneus* or *Mulloidichthys*) comprised over 90% of all prey deliveries to chicks from 1997 to 1999 (Ramos 2000). In both 1997 and 1998, periods of good food supply were interrupted by one period of low food delivery, lasting up to two weeks in 1997. During those periods alternative sources of food were apparently scarce (Ramos 2000).

During the 1998 successful breeding season, Roseate Terns foraged within dense flocks of lesser noddies (*Anous tenuirostris*), which in turn were associated with predatory fish. roseate tern feeding flocks over predatory fish were significantly larger, with individual birds increasing significantly their foraging attempts than those birds in the absence of predatory fish (Ramos 2000). During the 1999 failure season, most roseate tern flocks were either monospecific or mixed with fairy terns, and no dense feeding flocks or activity of predatory fish were detected (Ramos 2000). As a consequence, food shortage in 1999 may have been more general: it could be related to the death of the coral reefs, which, in turn, could be responsible for a poor recruitment of mullids.

In 1998 virtually all feeding flocks were multispecific and were over blue-water > 200 m from the coast. In contrast, in 2001, although feeding flocks were not recorded systematically, many roseate tern flocks were monospecific and were observed < 200 from the coast (at least on 6 days birds were feeding on the break of the waves, diving in water of 10-20 cm deep). It must be noted that clupeiod fishes (Clupeidae and Engraulidae) comprised an important proportion of the diet in 2001 (Ramos & Pacheco 2001). The size of non-mullids taken in 2001 (and therefore their profitability) were much larger than those of mullids, and, apparently, some adults specialised on their capture. Large multispecies feeding flocks over predatory fish in 2001 seemed much less common than in 1998.

Factors influencing breeding success

Three main factors affect roseate tern breeding success on Aride: (1) food shortage, (2) tick infestation and (3) intraspecific aggression by Roseate Tern adults on chicks (Ramos 1997, 1998b, 2000, 2001, Ramos *et al.* 2001). The first factor is by far the most important; the other two factors being dependent on the extent of food shortage. In 19 years of monitoring on Aride, roseate terns failed almost completely during half of them (Table 2). Table 1 clearly shows that breeding failures are connected with later breeding. Even during early breeding years such as in 1998 there are periodic food shortages (Ramos 2000, 2001). The main factor limiting hatching success is food shortage. In years, such as in 1997, when eggs are left unattended for long periods (over ½ h) they may be rolled by Wright skinks *Mabuya wrightii* until they break against a rock (Ramos 2001, Maul 1998). Otherwise, no other type of egg predation has ever been recorded. Therefore, although Wright Skinks are the proximate cause of egg predation, the ultimate main factor appears to be food shortage, which must explain high rates of eggs unattended by adults in certain years.

Before periods of food shortage chick growth was correlated with egg size, suggesting that, if food is abundant, intrinsic factors (parental "quality") are the primary determinants of chick growth and survival (Ramos 2001). However, since 1997 food shortage has severely limited chick growth in 3 of 4 years of a chick growth study (Ramos 1999, 2001, Ramos &

Pacheco 2001) and should explain the almost complete breeding failures registered in 10 of 19 years of monitoring on Aride (Table 2). Lack of predatory fish to drive prey to the surface (Ramos 2000) may contribute to explain intermediate periods of food shortage. However, Ramos *et al* (in prep.) showed that breeding failures are connected with later breeding, which, in turn, might be a consequence of a food supply reduction in certain years.

Tick infestation and adult intraspecific aggression limit also chick survival but are additive to food shortage. During periods of food scarcity ticks speed up chick mortality (by exsanguination and possibly through diseases transmitted by tick-borne viruses; Ramos *et al.* 2001) and newly hatched chicks are more prone to attacks of adults (Ramos in prep.). In 1998 it was estimated that ticks and intraspecific aggression alone were responsible for the death of 24.3% and 8% of the chicks, respectively. Ticks may also influence post-fledging mortality, because nestlings infested with ticks fledge later (and presumably in poorer condition) than noninfested chicks (Ramos *et al.* 2001).

Productivity (chicks raised per pair per year) is the product of four variables: clutches laid per year x clutch size x hatching success x chick survival. Renesting has occurred mainly in certain years of early breeding such as in 1988 and 1994 (Table 1). Presumably birds that fail the first breeding attempt (in 2000 a new influx of breeding birds appeared on Aride one month after the beginning of the breeding season, Hunter & Bradbury 2001) renest if food conditions do not deteriorate or improve visibly. Mean clutch size varies among years from 1.03 to 1.55. This variability may depend on food availability early in the breeding season and the timing of breeding (Table 1).

Discussion

Limiting factors

The monitoring and research results clearly indicate that food shortage is the main factor limiting roseate tern breeding success on Aride. Early reports (McCarthy 1986, Bullock 1989) suspected that disturbance could have strong adverse effects on breeding success, but careful monitoring and research activities conducted on Aride (Ramos 2001) and elsewhere (Nisbet 1981, 1989, Gochfeld *et al.* 1998, Nisbet & Spendelow 1999, Zingo et al. 1997) do not have a significant impact on roseate tern productivity.

The reasons behind the frequent food shortage appear to be related, at least in part, to the specialised foraging behaviour of the roseate terns. They are specialised on factors that make prey available to them, especially predatory fish, although wind strength, upwelling and marine currents may also be relevant in certain years or periods within a year (Shealer 1996, Ramos 2000, Ramos & Pacheco 2001). Aride roseate terns have developed adaptations to breed under stressful conditions, especially the fact that they seem to sacrifice clutch size and/or egg size for early laying (Ramos 2001, 2002). This suggests that food scarcity is not a recent factor affecting roseate terns, but, instead, appears to have been an important historical factor shaping evolutionary breeding adaptations.

The negative correlation between the multivariate El Niño index and timing of breeding suggests that oceanographic variables over a relatively larger scale influence the timing of reproduction (Ramos *et al.* in prep). Moreover, the size of the breeding population was inversely correlated with sea-surface temperature. Since high sea-surface temperatures are connected with low productivity this means that annual variations in marine productivity may be

the ultimate factor determining roseate tern timing of breeding and, therefore, productivity (Ramos *et al.* in prep.). The influence of oceanographic conditions on adult survival is unknown. The underlying causes of definite periods of food shortage within a breeding season are partly unknown and difficult to predict. Information on the ecology and movement patterns of predatory fish around Aride is necessary to fully assess and predict the impact of predatory fish on food availability. Aride roseate terns seem to rely heavily on Mullidae (although other schooling fish are readily taken if available. Ramos & Pacheco 2001) so it would be important to investigate the factors that influence recruitment of mullids.

For the Northwest Atlantic population the main factors limiting the rate of increase seem to be demographic: especially low annual survival rate and probably a low survival between fledging and first breeding (Spendelow *et al.* 1995). Studies of demographic parameters for the Aride population have only just began. Fledglings were ringed in 1998 and 2001. Some of those ringed in 1998 returned to Aride in 2000 and 2001, so an effort to read the Roseate Tern special rings in future years is necessary in order to obtain information on recruitment rates and adult survival.

The strong annual variation in breeding numbers (Table 1) mean that there may be movements between colonies in the Indian Ocean or that some adults decide not to breed in certain years. The sudden influx of new breeding birds in 2000 (Hunter & Bradbury 2001) gives some support to this idea. Altogether this means that the study of demographic parameters must be viewed as a long-term study. The strong population crash between 1991-1993 parallels the crash of the roseate tern regional population in North America (Nisbet & Spendelow 1999). Therefore, the possibility that major changes in weather or oceanographic patterns may influence roseate terns on a global scale should be considered.

Most of the annual mortality of adults occurs after they leave Aride, but the postbreeding and migratory ecology of the roseate terns in the Indian Ocean is unknown. Hopefully the ringing scheme started in 1997 will shed some light on the postbreeding quarters of the birds.

Conservation and research

The research conducted on Aride-Roseate Terns has provided rigorous ecological information to serve as the basis for management planning. It was demonstrated that food shortage is the main factor limiting productivity. However, the factors that may enhance food availability are complex (involving underwater predators, physical oceanographic features of the ocean and, perhaps, prey recruitment) and not liable to any immediate management action. A possible link between tuna landings and tuna movements in the Seychelles bank, and Roseate Tern breeding success should be researched.

Although food supply is the main determinant of productivity, nothing is known of adult survival. The fact that productivity has been low means that for the maintenance of a stable population adult survival and longevity must be relatively higher. In temperate populations, productivity is high and adult survival is low, relative to those of other long-lived seabirds (Spendelow *et al.* 1995). Thus, management actions of temperate populations should be focused on actions to enhance survival, rather than on actions to enhance productivity (Nisbet and Spendelow 1999), but, at the moment, it is difficult to envisage any suitable management actions that would enhance survival of a long-lived migratory seabird whose postbreeding ecology is virtually unknown. Research into these areas remains the only key to

formulate possible management decisions.

Management actions to maintain and/or enhance suitability of colony and nest-sites (keeping open flyways through the forest canopy, adding stones and/or logs that may attract breeding birds to certain areas of the colony and/or prevent attacks of adults on chicks) can be carried out, but their overall impact on productivity is likely to be small (Ramos 1998a, 1998b, in prep).

The most critical parameters in need of research, adult survival and recruitment rates, require a "hands-on" study (Nisbet & Spendelow 1999). Tropical roseate terns are more sensitive to disturbance than their temperate counterparts (Ramos 2001, in prep.), but with appropriate precautions, especially the construction of shelters for newly hatched chicks, nestlings can be ringed and weighed with minimal adverse effects (Ramos 2001). The acquisition of knowledge on these parameters will take a very long time if only chicks are ringed, because of the frequent breeding failures. Apart from one adult entangled with a string, breeding adults have not yet been ringed. Unlike their temperate counterparts they do not leave hatching eggs or newly hatched chicks and could be caught by hand at the appropriate time of the breeding season.

Finally, the knowledge acquired from the research on Aride Island may have important implications for the conservation of the roseate tern throughout the tropics.

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